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## *FOREWORD*

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ALL scientific men, and especially astronomers, will be grateful to Dr Steavenson for having gathered together, and to the Optical Society for having published, these details about Sir William Herschel's telescopes. This paper helps us to appreciate one aspect of Herschel's many-sided genius. The mechanical and optical skill shown in the design and construction of his telescopes is wonderful. To this Herschel added incomparable industry and power of observation. Greatest of all was the insight and imagination with which he interpreted the facts which he made his telescopes reveal. The discovery of Uranus, the first addition in historical times to the number of the planets, was his first great achievement But his greatest triumphs were in the field of stellar astronomy. Whatever shone was to be observed, and whatever was observed as far as possible interpreted. He gave us, as a result, a picture of the sidereal universe, essentially correct both in form and scale. He boldly interpreted the community of proper motion of a few stars as indicating the motion of the Sun and planets through space. He enriched our knowledge by the discovery of double-stars, clusters, and nebulae.

The telescopes he constructed with his own hands were the instruments he designed and used in these great discoveries. They are of interest as works of art, but still more as the tools which the Father of Stellar Astronomy employed to demonstrate to us the nature and vast extent of the Sidereal System.

Dr Steavenson's paper is of value as showing us what these telescopes were and what was involved in their manufacture, and is a pious tribute to one of the greatest of astronomers.

# A PEEP INTO HERSCHEL'S WORKSHOP

By W. H. STEAVENSON, F.R.A.S.

*Read and discussed, 15th January, 1925.*

*ABSTRACT.* A description is given of the results of a recent examination of such instruments and apparatus of the great astronomer as are still preserved at Slough, where the bulk of Herschel's optical and astronomical work was done.

Those items of the collection which are of a purely optical nature include: (1) one of the mirrors of the great 40-foot telescope, (2) one of the three mirrors of the 20-foot telescope, (3) some smaller objective mirrors, (4) a number of flats, (5) various eyepieces and micrometers in brass and wooden mounts, and (6) a complete 7-foot telescope on its original mounting.

All the objects in the collection have been cleaned, measured, and permanently marked for future identification, and a descriptive catalogue* has been compiled.

## Introduction

Sir William Herschel's great reputation as an astronomer has perhaps in some measure overshadowed and obscured his almost equal claim to fame as a master of practical optics. Of course, the part played by him in developing and popularizing the reflecting telescope is a matter of history. That is to say, it is well enough known that he succeeded in producing larger mirrors than any of his predecessors, that he ended by constructing as early as 1789 an instrument that would rank as large even to-day, and that he clearly demonstrated the general efficiency of his products by the observational work which he himself accomplished by their aid. But, when we come to enquire more closely into the technical details of his optical work (such as the methods used by him in grinding and polishing his mirrors, the quality of the figure which he succeeded in giving to the latter, and the exact optical and mechanical construction adopted by him for his eyepieces and micrometers), it is by no means easy to obtain much definite information from any published sources. No doubt this is partly due to the fact that Herschel himself was not a little reticent in regard to these matters, so far as actual publication was concerned. We must remember that these things were to him in the nature of trade secrets, and we cannot blame him for being unwilling to risk the loss of what was practically a monopoly and certainly a substantial means of livelihood. On the other hand, he evidently did not intend to allow the results of his experience to be lost to the world at his death, for he left behind him, in MS. form, four complete volumes of notes relating to his various processes and experiments, and also a complete treatise on mirror-making, in which he sums up the results of forty years' experience in the art. These valuable manuscripts are now in the

* See p. 221.

possession of the Royal Astronomical Society, together with others of a more purely astronomical kind. It is greatly to be desired that means should some day be found for publishing them; but, meanwhile, it would no doubt be possible for those particularly interested in their contents to consult them, on making application to the Council of the Society.

But there is another and more obvious method of forming an estimate of Herschel's ability as an optician, and that is by an examination of actual specimens of his handiwork. It is rather remarkable that this does not seem ever to have been done in a business-like manner. This has certainly not been from lack of opportunity, for Herschel made and sold reflectors by the score, and examples of his work found their way into all parts of Europe. Naturally, many of these cannot now be traced, but, on the other hand, several survive practically intact, and their whereabouts is known. Possibly some have been subjected to critical tests, but I am not aware of any published account such as would enable us to come to a definite conclusion as to their quality. If those who have access to these old instruments could be persuaded to carry out such tests and report the results to this Society, we should doubtless secure information of the greatest historical interest and value.

If this is too much to hope for, something might at least be done by way of compiling a sort of census of Herschel's surviving telescopes. Otherwise it is to be feared that they may one by one drop out of sight, as so many have already done in the course of the past hundred and fifty years. It is in this direction that I have myself endeavoured to make a modest beginning. Thanks to the kindness of the Herschel family, I was provided with the most desirable of all starting points, namely, the instruments actually in the possession of the great astronomer at the time of his death. These are still preserved at the old house at Slough, where the bulk of his work was done and where two of his grand-daughters still reside. Here I was privileged, in the summer of 1924, to examine what remains of the collection, and at the same time to compile a descriptive catalogue of the various items, which number about 150.

It may be of interest if I now give a brief account of those which are of a purely optical nature. These include (1) the mirror of the famous 40-foot telescope; (2) one of the mirrors of the 20-foot telescope; (3) a number of smaller objective mirrors; (4) flats of various sizes; (5) eyepieces in brass and wooden mounts, and (6) a complete 7-foot telescope.

### (1) Mirror of the 40-foot Telescope

Strictly speaking, this most interesting relic would be more correctly described as *one* of the mirrors of the telescope, for there were originally two of them, each 48 inches in diameter and of 40 feet focal length. The first was cast in 1785, but, owing to its being too thin (about $2\frac{1}{8}$ inches) it would not keep its figure when placed in the telescope. It was, however, used until a thicker mirror was completed in 1789, after which it appears to have been put aside and little, if at all,

used. Strangely enough, it cannot now be found, though it is known to have been in existence as recently as the sixties of last century. It is unlikely that it was destroyed, and it is thought probable that it was buried or bricked up somewhere in the grounds of Observatory House.

It is, then, the second and better of the two mirrors that is still preserved. 3½ inches thick, and weighing about 19 cwts., it rests on its edge (in its original annular cell of cast-iron) against the wall of the entrance hall of Observatory House. The weight is supported from below by a stout beam, let into the stonework, while an iron hook, projecting downwards from the arch above, is inserted into the cell as a precaution against forward tipping. The back of the mirror is not visible, but is believed to be slightly convex, producing an approximate equality of thickness in all parts. Presumably this was intended to guard against flexure, and to reduce the effects of changing temperature.

The reflecting surface has naturally suffered much from exposure, for it has never been completely protected from the air since it was last polished in 1809. Actually there is but little discoloration, the dulness being mainly due to a more serious cause, namely a fine pitting of the entire surface. To this is added a curious and regular mottling, visible only in certain lights. It resembles the effect produced by frost on a window-pane, or the surface of freshly-galvanized iron, and is apparently due to chemical action exerted by the atmosphere on the alloy of which the mirror is composed. But, in spite of all this, a certain amount of polish still exists, and suitably lighted objects are quite clearly and recognizably reflected. It is not, of course, possible in such a confined space to make any tests of the mirror's figure, but it is perhaps doubtful whether this could now be done satisfactorily under any conditions, owing to the present state of the polish.

It is well known that Herschel did not do very much serious work with his great 40-foot telescope, preferring to use the 20-foot and those of still smaller size. This fact has given rise to the suggestion that the defining power of the large mirror was of an inferior order; but, in view of the fact that Saturn's most minute satellites could be followed with it right up to the limb of the bright planet (and this in spite of the astigmatism produced by the tilting of the mirror), we must conclude that the suggestion is ill-founded. Any astronomer who has attempted to observe faint satellites with a large aperture on an unsteady night knows well enough that mere light-grasp without good definition will not alone suffice to reveal stellar objects of this kind. It seems far more probable that Herschel's preference for the smaller instruments was due to the greater ease with which they could be manipulated, the larger fields of view afforded, and the rapidity with which the tarnished mirrors could be re-polished. Indeed, we may even conjecture that the monster instrument was something of a nuisance to its constructor, for by its very size it undoubtedly attracted large numbers of visitors to the great astronomer's house at Slough, and much valuable time must have been spent in demonstrating to them the "show" objects of the sky. The books in which Miss Caroline Herschel recorded the names of these visitors (or as many of them as she could remember after their departure) are still

preserved, and a glance through them makes one wonder how her brother ever found enough time for his more serious work. His notorious patience and urbanity must have been sorely tried under such conditions, and he may even have been tempted at times to wish that he had never constructed such a prodigy among telescopes.

### (2) Mirror of the 20-foot Telescope

The instrument to which this mirror belongs was the one used by Herschel for most of his more important work. Like the 40-foot, it originally had two specula, each of which was used in turn while the other was being polished. One of these is now at the Royal Observatory, Cape of Good Hope, and the other at the Radcliffe Observatory, Oxford. Both were made by Sir William alone; but, a few years before his death, a third one was made by himself and his son, working together. This is the one which is still to be seen at Slough. Like the others, it has a figured surface 18·7 inches in diameter, and is about $1\frac{1}{2}$ inches thick. It is protected by a loose-fitting tin cover, and rests in a square wooden case. The surface is in very good condition, but it is to be remembered that it was polished as recently as 1837, having been used, with the two other mirrors, at the Cape by Sir J. F. W. Herschel, to whom its present figure is entirely due.

During the evening of 1924, May 14 it was tested at the centre of curvature by Foucault's method. The temperature was falling slowly and steadily and the conditions were approximately those which would obtain during actual observations with the mirror. As seen under the knife-edge, the entire surface was remarkably smooth and free from rings and other irregularities. It was, however, clear at the first glance that the mirror was considerably over-corrected. With the relatively large focal ratio of 1 : 13·3 the departure from a sphere should scarcely have been perceptible; yet prominent shadows were visible, as in a truly-corrected mirror of much smaller focal ratio. Evidently, then, the figure was markedly hyperbolic, and this was confirmed in a quantitative way by a zonal test. The theoretical differences of the values of $r^2/R$ for the two zones selected were respectively ·077 inch and ·124 inch, taking a third zone as zero. Actually, a mean of six measures yielded values of ·919 inch and 1·292 inches*. Such a large amount of over-correction would, of course, make it impossible for the mirror to form critical images; but, taking into account the great focal ratio and the fact that the 20-foot was used chiefly for the discovery and examination of nebulae and star clusters with low powers, this considerable departure from the true paraboloid was not of much consequence. When it was first constructed, the 20-foot was used with a flat, i.e. as a Newtonian; but Herschel soon discarded the small mirror to gain more light, and never reverted to the other form, though it was retained in all his smaller instruments. For the 40-foot the front-view method was alone employed from the first.

* For details of individual measures see *The Observatory*, 47, p. 304.

### (3) Smaller Objective Mirrors

There are twelve of these, mostly enclosed in metal cases with close-fitting lids. Table I gives the essential particulars of them.

Table I

| Catalogue designation | Material | Construction | Diameter of figured surface ins. | Focal length ft. | ins. |
|---|---|---|---|---|---|
| (A) | Metal | Gregorian | 9·0 | 5 | 2·5 |
| (B) | Metal | Gregorian | 7·05 | 6 | 3·5 |
| (C) | Metal | Gregorian | 5·9 | 2 | 9 |
| (D) | Glass | Newtonian | 6·5 | 7 | 1·75 |
| (E) | Glass | Newtonian | 8·6 | 10 | 3 |
| (F) | Glass | Newtonian | 6·48 | 7 | 3·25 |
| (G) | Metal | Newtonian | 5·0 | 1 | 6± |
| (H) | Metal | Gregorian | 3·0 | | 6± |
| (J) | Metal | Newtonian | 8·8 | 10 | 1 |
| (K) | Metal | Newtonian | 8·85 | 10 | 3·25 |
| (L) | Glass | Newtonian | 9·0 | 10± | |
| (N) | Metal | Newtonian | 8·8 | 10 | 0 |

It will be noticed that the above list contains four Gregorian mirrors, whereas it is known that Herschel used unpierced specula almost exclusively. Indeed, it seems highly probable, from their general appearance, that (B), (C), and (H) are not the work of the great astronomer. On the other hand, it is certain that this does not apply to (A), which is the mirror of what Herschel called his "five-foot sweeper"; this he specifically mentions as having been cast with a central hole, for use as a Gregorian if desired. The remaining specula, with the possible exception of (G), are certainly Herschel's work, for, apart from their characteristic appearance, they all conform to one or other of the two sizes adopted by him for the great majority of his specula, namely the "7-foot" and the "10-foot." Of these, the former always had a figured surface of about 6·5 inches diameter, and the latter one of approximately 8·8 inches.

Possibly the most interesting of the mirrors are those designated (D), (E), (F), and (L), for they afford evidence of a fact not generally recognized, i.e., that Herschel successfully used glass as a material for the construction of telescopic mirrors. (D) and (E) are mounted in brass cells, with a backing of dark velvet, and were used for solar observations. (F) is a unique and remarkable specimen, for the material in this case is described by Herschel as "Tassi's compound, or white glass." It has the appearance of porcelain, being of a somewhat denser whiteness than the familiar "opal" glass of a common lamp-shade, and has an excellent polish. Herschel says of it "I find by experiment that it reflects double the quantity of light reflected by common glass." We are not told what use he made of it, and this appears to be the only one he constructed, which enhances its value as an optical relic. (L) is an unfinished mirror, the polish being incomplete towards the edge. It is only $\frac{1}{8}$ inch thick, and exhibits such violent signs of flexure when placed on its edge that it is impossible to obtain a clear image with it. It was probably for this reason that work on it was abandoned when it was but half finished.

The remaining mirrors, (A), (J), (K), and (N), are of speculum metal. The first

is considerably tarnished, having been much used by its maker and his son, and having had no cover to protect it from the air since that time. On the other hand, (J), (K), and (N) are in remarkably fine condition. Apparently they have never been used, and they were soldered down in tin cases by Herschel. Probably they were intended to be disposed of with a certain 10-foot telescope which was still unfinished at the time of his death, in 1822. Thus they had been kept from the air for over a century when their cases were opened in 1924, May. The polish of the surfaces was then found to be in a splendid condition, there being no trace of tarnish on any of them.

A somewhat rough zonal test of all the mirrors (except (G), (H), and (L)) was made in the cellar at Slough in 1924, May. Most of them were found to be somewhat over-corrected, as is frequently the case with mirrors of large focal ratio; but one or two were so closely spherical, as seen under the knife-edge, that no satisfactory zonal test could be made. Nearly all the mirrors were affected by two or three narrow zones of long or short focus. These are probably traceable to Herschel's use of the side-stroke for parabolization, instead of the modern method of trimming the polisher.

On the whole, it may be said that the figure of all the mirrors was up to a very fair standard, and, having regard to their great focal ratio, it is probable that they performed quite well in actual use. With the one exception already quoted, there was no sign of flexure in any of the mirrors when they rested on their edges. The tests made in 1924 were only intended to be of a preliminary character, and it is to be hoped that more exact ones will be carried out at some future date, preferably by the Hartmann method.

### (4) Flats

There are, in all, 30 of these, ranging in diameter from ·55 to 3·1 inches. The majority are provided with close-fitting brass covers and their polish is in good condition. They are for the most part of two standard sizes of minor axis, 1·1 and 1·5 inches respectively, according as they were intended for use with 7-foot or 10-foot telescopes. No critical test of the truth of their surfaces has yet been made, though a reference will be found later to the performance of one of them under observing conditions. Apart from the angle of their optical surfaces, most of the flats are cast as solid cylinders. This makes them unduly heavy, but simplifies the process of mounting and guards against flexure.

### (5) Eyepieces

There are 48 of these in a complete condition, and about half a dozen more in various finders and micrometers. Some are in brass and others in wooden mounts, these being probably the work of Herschel's brother Alexander, who appears to have done much of the purely mechanical work for the telescopes made at Slough. The lathe which was used is preserved in good condition, and is actually still in working order.

The eyepiece mountings are very simple, consisting in general of two portions, which, screwing together, confine between them a single convex lens. The latter is not cemented or otherwise fastened into place, though it is often maintained in centration by an annular excavation of appropriate size. Three or four of the lenses are concaves, but the great majority are of the equi-convex form. Herschel, as is well known, was strongly wedded to the single-lens form of eyepiece, and (with one exception) there is not a single Huygenian, Ramsden, or other double-lens form among his collection. It is not quite clear whether he himself actually made the lenses used in all his eyepieces, but some at least were, as we shall see, of a kind that would scarcely have been obtainable from the ordinary optician of that day.

Herschel's claims to have used powers between 1000 and 6000 on one of his 7-foot telescopes have been the subject of some controversy and not a little incredulity in the past. It therefore seemed to be of particular interest to find out whether he really possessed eyepieces which would yield such powers as these. Quite a short search sufficed to lay any doubts at rest by revealing no less than nine of these eyepieces, whose focal lengths and powers (on the telescope used by Herschel) were found by careful measurement to be as given in Table II.

Table II

| Catalogue designation | Focal length, inch | Power |
|---|---|---|
| ($D_{18}$) | 0·064 | 1331 |
| ($D_{19}$) | 0·046 | 1852 |
| ($D_{20}$) | 0·038 | 2242 |
| ($D_{21}$) | 0·024 | 3550 |
| ($D_{22}$) | 0·023 | 3704 |
| ($D_{23}$) | 0·0225 | 3787 |
| ($D_{24}$) | 0·019 | 4484 |
| ($D_{25}$) | 0·0175 | 4869 |
| ($D_{26}$) | 0·0111 | 7676 |

All of these are well-formed bi-convex lenses, with the exception of ($D_{21}$), which is a simple sphere. Two or three of them, including the smallest, were found to be somewhat astigmatic, and in some cases there were signs of devitrification of the surfaces; but in general they gave sharp images in the micro-focometer used, and their focal lengths were quite readily measured.

All were actually tested on celestial objects with a 6-inch Wray refractor in 1924, June, and were found to form recognizable (though of course dim and diffuse) images of stars and planets. Even ($D_{26}$), despite astigmatism and excessive power (about 10,000 diameters) showed the spurious disc of Vega, with portions of the first diffraction ring, and also exhibited the general outlines of the planet Saturn. The field of view was, however, only about twenty seconds of arc in diameter, and the image could hardly have been examined, or even held in view, without the help of a good clock-drive. And yet Herschel, in his experiments on high powers, had nothing better than an altazimuth stand with hand-driven slow motions!

We are told nothing of the methods employed in making these tiny lenses, the smallest of which is only $\frac{1}{45}$ inch in diameter. Compared with this, the front lens

of a modern 2 mm. oil-immersion objective is a large and clumsy object. It would be interesting to know exactly how a present-day optician would proceed, if required to make a duplicate of this most powerful of Herschel's eyepieces, fashioned in the eighteenth century.

### (6) The 7-foot Telescope

This is the only complete instrument in the collection. It stands in the entrance hall of Observatory House, and is in good condition and fair working order. Both tube and mounting are of mahogany, the former being of octagonal section, like all Herschel's smaller telescopes. The whole is almost exactly like the one to be seen in the Science Museum. Both mirror and flat were much tarnished, the cover of the former being far from air-tight, and the latter being without a cover of any kind. A good deal of the tarnish on both was removed by means of lemon juice, and a useful proportion of the original reflectivity was thus restored.

The large speculum, of diameter 6·2 inches and focal length 7 ft. 2¾ ins., was removed from the tube and subjected to a Foucault-test. The latter showed the figure to be beautifully regular, without a trace of rings. A measurement of the zones suggested the presence of a very slight degree of under-correction, the test being made under conditions of constant temperature. The mirror was then replaced in the tube, and the whole telescope taken out of doors for actual testing on celestial objects. For this, one of Herschel's own eyepieces was used, a single bi-convex lens giving a power of 361. No observations were made until the telescope had stood in the open air for several hours; but, even with this precaution, the effect on the mirror of a steadily falling evening temperature was very marked, for, whereas the figure had appeared slightly but definitely *under*-corrected at a constant temperature, it was now found to have passed through the paraboloid to a state of slight *over*-correction. However, definite rings were visible in the expanded images of stars on both sides of the focus, while at the latter itself there was nothing to indicate any departure from perfect correction.

Apart from the inevitable colour and loss of definition in the peripheral portions of the field (due to the form of the eyepiece), the performance of the telescope was most admirable. Of course, the light grasp was deficient, owing to tarnish, but it did not seem inferior to that of a 3-inch refractor, the companion of the Pole Star being easily seen. The detail on the Moon was as fine as that shown by any modern reflector or refractor of similar aperture, and Venus and Jupiter were exquisitely defined. Arcturus showed a neat disc with diffraction rings, which is more than is brought out by many modern reflectors.

It has often been suggested that Herschel's instruments, though marking a great advance on previous efforts, would not be accounted good according to present-day standards. Anyone holding such an opinion would, I think, feel inclined to revise it after a glance through this beautiful little 7-foot telescope.

No attempt has been made in this paper to give more than the briefest description of the more interesting items in the Slough collection. More complete details have been incorporated in the catalogue which follows.

## DISCUSSION

Mr D. Baxandall: I should like to express my thanks to Dr Steavenson for the interesting account which he has given us of the Herschel relics at Slough. His examination, testing, and listing of these important objects is a work of considerable historical value; and there is a sense of appropriateness in the fact that this work has been carried out by one of our most brilliant amateur astronomers.

This afternoon, in glancing over that delightful book, the *Memoirs of Caroline Herschel*, I noticed one of her letters which is interesting, partly from its date—it was written at Hanover to her nephew Sir John on January 14th, 1825; she was then nearly 75 years of age. The following are one or two passages from it. "I am now writing out the Catalogue of Nebulae, and am at zone 30°, and hope to finish it for the Easter messenger"—she finished it before March 7th. Referring to an account by Sir John of his father's life and work, she says: "I could point out three instances where too great a stress is laid on the assistance of others, which withdraws the attention too much from the difficulties your father had to surmount. (1) The favours of monarchs ought to have been mentioned, but once would have been enough. (2 and 3) Of Alexander and me can only be said that we were but tools, and did as well as we could, but your father was obliged first to turn us into those tools with which we could work for him; but if too much is said in one place let it pass; I have, perhaps, deserved it in another by perseverance and exertions beyond female strength! Well done!" As a postscript, she adds:

"Poor Sir William Watson!" (she had just been informed of his death).

The 7-foot Newtonian telescope belonging to the Science Museum was made by Sir William Herschel for Sir William Watson. The other precious Herschel relics in the museum include a similar but earlier instrument belonging to the Royal Astronomical Society, the original glass negative made by Sir John in 1839, spectroscope apparatus used by both Sir William and Sir John, and the original hand speculum polishing machine, exhibited here to-night.

## NOTES ON THE ILLUSTRATIONS

*Frontispiece.* So far as is known, no reproduction of this medallion has hitherto been published. Note the symbol of the planet Uranus, discovered by Herschel, and the representation of the famous double star system of $\epsilon^1$ and $\epsilon^2$ Lyrae. The authorship of the medallion is of special interest in view of the fact that for one of his mirrors Herschel made use of a composition invented by Tassie. [Catalogue reference (F).]

Fig. 1. Photograph taken in 1924, May. Observatory House is on the left. Part of the right-hand half is original, but the portion on the left is a comparatively modern addition. On the right of the centre is the "Cottage," referred to as "The Observatory" by Caroline Herschel. It has been considerably altered since her time, especially as regards its upper portion, but much of it, including the two ground-floor rooms, is substantially unchanged. The 40-foot telescope originally stood on the extreme right, where the flower beds are seen on the near side of the tree. The 20-foot stood a few feet on the near side of the Cottage, towards the left. The place was, when this photograph was taken, partly occupied by a clump of shrubs and small trees, seen between the central tree and the Cottage. Just to the right of the porch of the latter (which is modern) is a small tree, said to have been planted by Caroline Herschel. It is still alive and vigorous.

Fig. 2. This illustration, originally prepared under the direction of Sir William himself, shows very clearly the manner in which the great instrument was mounted. The two concentric brick walls, on which the whole mounting could be revolved, are still in existence, but lie entirely below the present level of the lawn.

Fig. 3. Photograph taken in 1924, May. The reflections here shown are somewhat clearer and more distinct than those seen visually, under ordinary conditions of lighting. Among the objects reflected will be seen the old Shelton Clock ($F_{17}$). Immediately to the left of the great mirror stands the Dollond burning lens ($F_{16}$).

Fig. 4. This surviving portion, 10 feet long, includes the end (on left) at which the great speculum was mounted. Note here the bracings of wrought iron and the lid, with original hasp and handles, covering the aperture through which the mirror and its cover were inserted. The whole tube, apart from the bracing, is of sheet iron, ·7 mm. thick. The remaining portion, 30 feet in length, was crushed by the fall of a tree in 1867. This photograph was taken in 1924, June.

Fig. 5. The circular brick wall, on which the whole mounting revolved, will be noted. A recent excavation (1925) has shown that it still exists intact, below the present level of the surface. Some portions of the mounting are still preserved (*f*).

Fig. 6. Photograph taken in 1925, March. The tube of the 20-foot rests horizontally on two upright wooden supports, one near each end. A portion of the brickwork circle lies under the shed, but the majority is outside. Its centre falls in the bare patch of earth to the right of the shed. A clump of small trees and shrubs marked this spot until early in 1925, when the ground was cleared (see Fig. 1). In the background, half hidden by the shed, is the original doorway of the "Cottage," It opens into the room shown in Fig. 12. The 7-foot telescope, in the foreground, usually stands in the hall of Observatory House.

Fig. 7. Photograph taken on the lawn of Observatory House in 1924, May. The large mirror, in case, is that of the 20-foot telescope (*g*). To the left of it will be seen the quadrant ($F_8$) by Bird, the smaller "zone clock" ($F_{20}$), the signal bell ($F_{18}$), and some micrometer eyepieces. To the right is the large "zone clock" ($F_{19}$), a finder ($F_3$), and some more micrometers. In front of these, on the right, are three pieces of polishing apparatus ($F_{24}$), ($F_{25}$), and ($F_{22}$). Immediately behind the small wooden eyepieces (standing on a box) is the mirror of white glass (F). Behind this again is one of the mirrors recently unsoldered (J).

Fig. 8. Photograph taken at Slough in 1924, October. All the items in sections A to E of the Catalogue are here shown spread out in order. In every case the numbers read from left to right, and the rows from behind forwards. At the back is row 1, containing all objects in Section E. Row 2 embraces ($D_1$) to ($D_{12}$); row 3 ($D_{14}$) to ($D_{34}$); row 4 ($C_1$) to ($C_{11}$); row 5 ($C_{12}$) to ($C_{28}$); row 6 ($B_1$) to ($B_9$); row 7 ($A_1$) to ($A_{10}$); row 8 ($A_{11}$) to ($A_{29}$); and row 9 ($A_{31}$) to ($A_{39}$).

Fig. 9. Photograph taken in 1924, June. The lens of the eyepiece can just be seen in the central aperture of the domed brass plate.

Fig. 10. Photomicrograph taken in 1924, June. The surfaces are seen to be not truly spherical, and their axes are neither coincident nor parallel. This gives rise to a considerable degree of astigmatism, as shown in Fig. 11.

Fig. 11. Photomicrograph taken in 1924, June. This is the aerial image formed by the mounted lens, working at an aperture of *f*/1, and then magnified 210 diameters. The effects of astigmatism are clearly shown.

Fig. 12. Photograph taken in 1924, October. To the left is Herschel's lathe ($F_{22}$). On the mantlepiece, resting on ($F_{28}$) and ($F_{27}$) is the "$3\frac{1}{2}$-foot Dollond" ($F_{18}$). On the wall above are two long frames of similar size and shape. They contain the discharges of Herschel and his father from the Hanoverian army. Duly signed and dated, they dispose of the baseless suggestion that the great astronomer was a deserter and later received a "pardon" from King George III. In this room most of the smaller relics connected with Sir William Herschel have been kept for many years.

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Thanks are due to Prof. F. J. Cheshire for permission to reproduce the Frontispiece, to the Royal Society for permission to publish Fig. 2, which has been copied from the *Philosophical Transactions*, to the Editors of the *Observatory* for the loan of the blocks for Figs. 3 and 7, and to the Royal Astronomical Society for the loan of the blocks for Figs. 9, 10, and 11. The remaining illustrations are from photographs taken by the author.

Fig. 1. Observatory House, Slough.

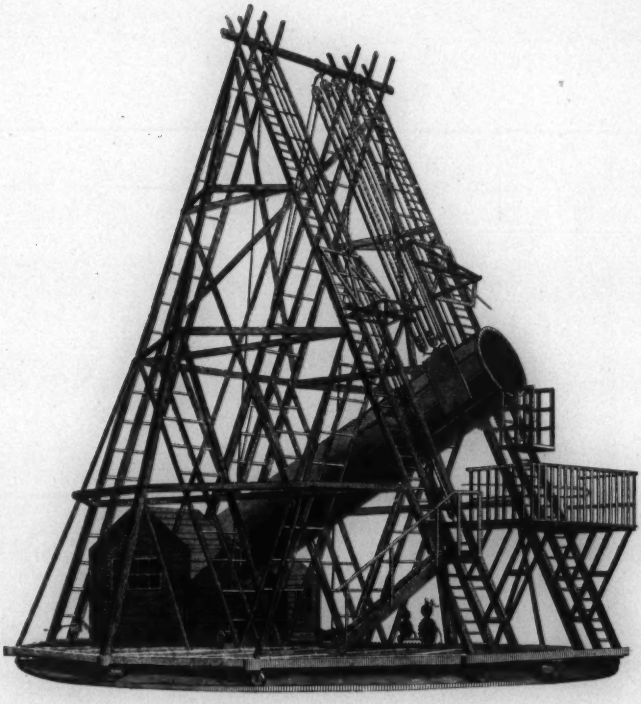

Fig. 2. Sir William Herschel's 40-foot telescope.

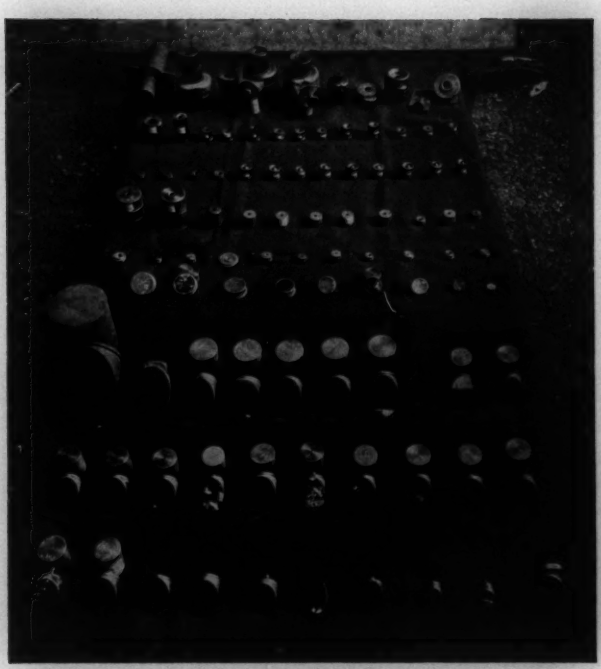

Fig. 8. Group of eyepieces and flats.

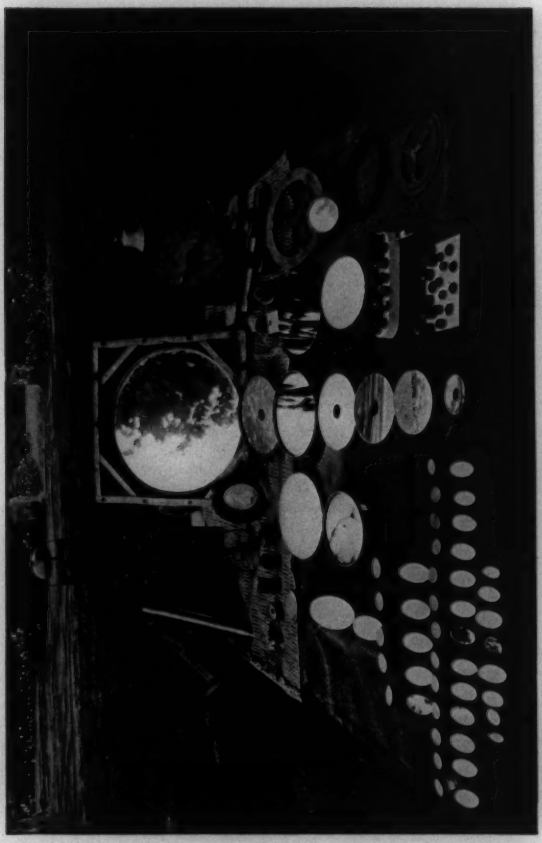

Fig. 7. Group of mirrors, flats, eyepieces, etc.

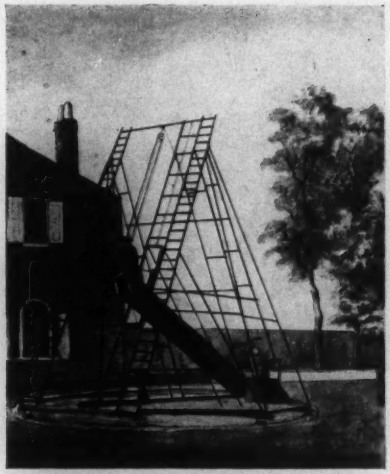

Fig. 5. The 20-foot telescope in use (from an old engraving).

Fig. 6. The 7-foot telescope and (in shed) tube of the 20-foot telescope.

Fig. 3. Mirror of the 40-foot telescope.

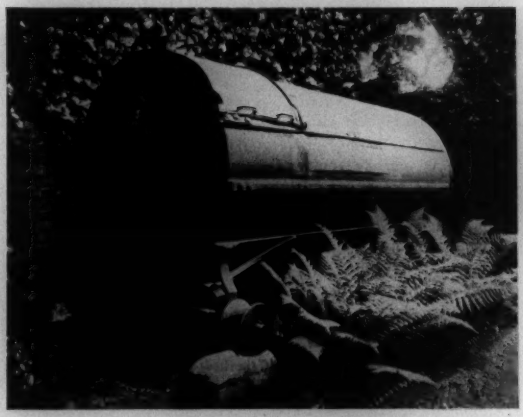

Fig. 4. Part of the tube of the 40-foot telescope.

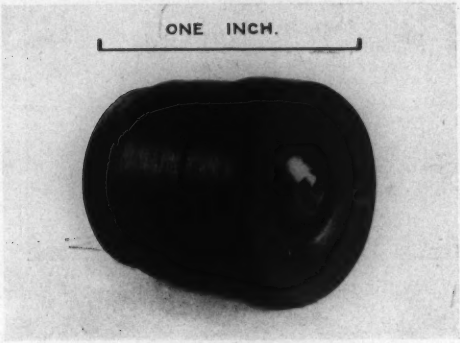


Fig. 9. Herschel's most powerful eyepiece.

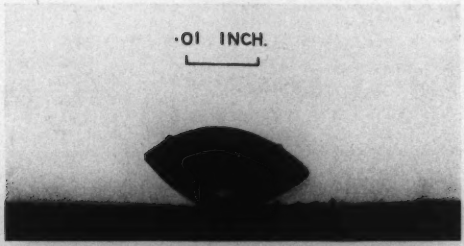


Fig. 10. Lens of Herschel's most powerful eyepiece.

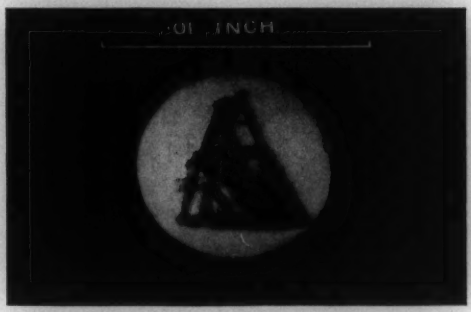


Fig. 11. Image formed by the lens of ($D_{12}$).

Fig. 12. A room in the "Cottage."

# CATALOGUE OF INSTRUMENTS MADE AND (OR) USED BY SIR WILLIAM HERSCHEL, AS PRESERVED AT SLOUGH AND EXAMINED THERE IN 1924, MAY AND JUNE

By W. H. STEAVENSON, F.R.A.S.

## INTRODUCTORY NOTE

In the following pages are listed, in some cases with a brief description, all the instruments and apparatus of Sir William Herschel to be found on the premises of Observatory House, Slough (including the "Cottage") in 1924, May and June. Except in the case of larger pieces of apparatus, where no errors of identification are at any time liable to occur, each item has been marked distinctly in a more or less permanent fashion, so that it may be checked and identified at any subsequent time by comparison with this list.

All optical surfaces were carefully cleaned, except in certain cases in which this was not considered necessary or advisable. Notes as to what was or was not done in this respect are made in each case.

Except where otherwise stated, all apparatus was found and left in the "Cottage," on the ground floor.

The cleaning, examination, and cataloguing of the instruments was done with the help of Mrs Maclear, Miss F. Herschel, Lady Lubbock, and Miss Eileen Herschel.

Of those articles which have been marked, the smaller mirrors have been given letters only; e.g. A, B, C, etc. The remainder have been divided into sections (A, B, C, etc.), each item in a section being marked with a number in addition to its sectional letter, as: $A_1$, $A_2$, $B_1$, $B_2$, etc. In every case the letter and number have been inscribed in a rough circle*. This serves definitely to distinguish the marks made in 1924 from any previous or subsequent marks.

The sections into which the apparatus has been divided, for marking, are as under:


| Marking | Nature of Apparatus | Page |
|---|---|---|
| Unmarked | Various large instruments, etc. | 222 |
| Capital letters only | Smaller mirrors | 224 |
| A | Elliptical plane mirrors for Newtonians | 231 |
| B | Secondary mirrors for Gregorians | 232 |
| C | Eyepieces with brass mounts | 233 |
| D | Eyepieces with wooden mounts | 234 |
| E | Micrometers with wooden and brass mounts | 235 |
| F | Miscellaneous apparatus | 237 |


In cases where a piece of apparatus can be identified with certainty or reasonable probability, a reference is made to the volume and page of the *Collected Scientific Papers of Sir William Herschel*† in which mention is made of it.

* In order to avoid the use of special type, the circled letters are printed in this catalogue with simple brackets, thus ($D_3$).

† Referred to as *C.S.P.*

## LIST OF INSTRUMENTS, ETC.

### 1. Unmarked Apparatus

(*a*) *Mirror of 40-foot Reflector*

This is mounted against the south wall of the entrance hall, in a recess. The surface is clean and not much *discoloured*, but the reflection of objects in it is rendered very diffuse by a fine and universal pitting of the surface, due probably to exposure in the telescope before it was dismounted. The mirror, set in its original iron ring (*C.S.P.* I, 524, 526, illustration), rests by its own weight on a stout beam. The large iron hook, set in the masonry above the mirror, does not take any of the weight of the latter. No test of the figure of the mirror could be made in such a confined space and, in view of the pitting of the surface, no attempt was made to clean it, since it could never under any circumstances give a clear reflection now. This is the thicker and better of the two 4-foot mirrors. The other cannot be found (see *C.S.P.* I, lv).

(*b*) *Tube of 40-foot Reflector*

All that remains of this, after the accident of 1867 (*C.S.P.* I, lxiv), now rests in a horizontal position close to the east wall of the garden. It is about ten feet long and includes the mirror end (see *C.S.P.* I, 503, illustration).

The other end has been fitted with a permanent cover of thin metal, in which a small trap-door is set. The section of tube is well painted and in excellent condition inside and outside. In it is the original cover of the 4-foot mirror, with handles complete (see *C.S.P.* I, 526, illustration).

(*c*) *Grinding and Polishing Apparatus for 40-foot Mirror*

A circular iron frame, 4 ft. 6 ins. in diameter, with ratcheted arcs, used for polishing the mirror. It hangs on the north wall of an attic in the cottage.

Two iron discs, 4 ft. in diameter and 2 ins. thick, used for grinding mirror. One of these lies exposed in the centre of the lawn, in or near the middle of the area originally occupied by the mounting of the 40-foot telescope. The other is buried a few feet to the south-west of it, at a depth of about 15 inches.

(*d*) *? Grinders for Large Mirrors*

These are two iron discs, much rusted, which lean against the wall behind the section of the 40-foot tube. One is 34 ins. in diameter, 1 in. thick, and pierced by a central hole 5 ins. in diameter. The other is 21·5 ins. in diameter, 1·75 ins. thick, and solid throughout.

(*e*) *A 7-foot Reflector*

This instrument stands in the entrance hall of the house. It is made of mahogany, the tube being octagonal in section, and is mounted on a stand with motions in altitude and azimuth. Azimuth motion is by worm and handle, altitude by rackwork to upper and cord and pulleys to lower end of tube. There is no eyepiece

in the tube, but mirror (M) and flat ($A_{20}$) are in place. For details of these see later. The supports of the finder are defective, especially the lower one. The arm supporting the flat is somewhat loose at the point of its attachment to the eye-piece slide.

(*f*) *Parts of the 20-foot Reflector*

These were, in 1924, May and June, in the loft* over the coach-house that is reached by an outside staircase of wood. They consist of (1) the original octagonal wooden tube of the telescope, in good condition, (2) sundry portions of the mounting, consisting of oak beams, iron cog-wheels and numbered plates, iron and bronze rollers and pulley-wheels, iron hooks, bolts, etc., (3) a circular frame of thin iron, probably used to hold the mirror for polishing, and (4) a heavy bronze disc, about 15 ins. in diameter, with smooth face and radially-ribbed back with central screw thread. Exact purpose doubtful: possibly a grinder for the mirror.

(*g*) *Mirror of the 20-foot Reflector*

This is one of three, taken to and brought back from the Cape by Sir J. F. W. Herschel. The other two are, respectively, at the Radcliffe Observatory, Oxford, and at the Royal Observatory, Cape of Good Hope. This one at Slough was "No. 3," and was made by Sir William and his son working together. Its diameter is 18·7 ins., and it rests in an iron cell, covered by a tin lid, the whole being in a square wooden box with lid and iron handles. The polish is in good condition, and there is very little tarnishing, except for two or three small patches. The present figure of the mirror is due to Sir J. F. W. Herschel. An account of an examination of it by Foucault's method (carried out by Rev. C. D. P. Davies, Rev. Sir J. C. W. Herschel, and W. H. Steavenson on 1923, June 26) appears in *M.N.R.A.S.* 84 (1923–24) 23. It was then found that the aberrations at the centre of curvature were about *five* times as great as they should theoretically be for a true paraboloid; that is, the mirror was *over*-corrected by this amount, being hyperboloidal in figure. The test was made under a slowly-rising temperature. In 1924, May, two further tests were made, of a similar kind, by W. H. Steavenson. The first was made on May 13 under a practically constant temperature. It showed a correction about nine or ten times in excess of the theoretical value. The second was made on the evening of May 14, 8–10 p.m., under a slowly falling temperature. It showed a correction about *eleven* times in excess of the theoretical value. The general figure is very regular and free from zones, humps, and hollows. The mirror probably performed quite well with medium and low powers.

No attempt was made to clean or renovate the surface in any way, beyond the removal with cotton-wool of a thin coating of dust.

* Early in 1925 the tube and other parts of the 20-foot reflector were removed from the loft to a position, south of the cottage, close to that originally occupied by the telescope when in use. They are protected by a wooden shed, specially built for the purpose.

## 2. Marked Apparatus

### *Small Objective Mirrors*

These range in diameter from 3 to 9 inches, and are of speculum metal or glass. All except three ((J), (K), and (N)) required cleaning, as noted later, and they were then tested by Foucault's method in the cellar of Observatory House, which is lit by a single gas jet. The smallest mirror, a 3-inch Gregorian of very short focus, could not be satisfactorily tested by this method with the apparatus available.

Each mirror, together with its cell or case if it possesses one, has been marked in dark red oil paint, the letter in every case being surrounded with a rough circle.

Where a zonal test was made, reference is given to the number of the zone measured. These zones were all 0·4 inch wide, and were cut in one piece of pasteboard. The radii of the several zones were as follows:

| Zone | Radius of centre inch |
|---|---|
| 1 | 0·6 |
| 2 | 1·4 |
| 3 | 2·2 |
| 4 | 3·0 |
| 5 | 3·8 |
| 6 | 4·6 |

Only two zones were measured in each case, and the differences of focal length (for rays from centre of curvature) between the two is given in the form

$$\Delta\ 1 - 3 = 0{\cdot}282 \text{ inch, etc.}$$

### (A)

A Gregorian mirror of speculum metal in iron cell, the latter perforated at the back and fitted with an iron handle formed by the crossing of two strips of this form ⌐¬. No cover was found for the cell, and the mirror must have been exposed for a great number of years. The clear aperture of the mirror within the rim of the cell is 9·0 ins. A thick coating of dirt and tarnish was removed by (1) ether and (2) lemon-juice, both applied with pledgets of cotton-wool. However, there still remains a deep tarnish which cannot be removed, and in addition the surface, when seen in certain lights, is marked with a crystalline pattern, similar to that observable on sheets of galvanized iron. It probably has its origin in a faulty mixture of the components when first cast. A similar thing is to be seen in the case of the 4-foot speculum in the hall.

*Dimensions, etc. of mirror*

| | |
|---|---|
| Total diameter of figured surface | = 9·3 ins. |
| Clear aperture in cell | = 9·0 ,, |
| Diameter of central hole | = 1·23 ,, |
| Focal length | = 5 ft. 2·5 ins. |

*Results of Foucault test*

Tested on 1924, May 12, between 8.30 and 9.0 G.M.T.
Temperature at 8.30 = 52°·5 F.
,, 9.0 = 52°·6 F.

*General figure of mirror*

Very even, but there is a narrow and shallow zone of long focus about 1 inch from the outer edge.

*Zonal test*

Measured $\triangle 2 - 5 = 0{\cdot}144$ inch. Theoretical $\triangle 2 - 5 = 0{\cdot}10$ inch.

The mirror is therefore slightly over-corrected, as examined under a practically constant temperature.

*Note.* This is evidently the mirror of the "5-foot sweeper" whose tube has been lost sight of. (See *C.S.P.* I, xxv, xxxviii, lv, lvi, and II, 44, note.)

A loose-fitting pasteboard cover has now been fitted as a temporary protection.

(B)

A 7-inch Gregorian mirror of speculum metal, without cell, lying loosely in a tin case with cover. It was cleaned with ether and lemon juice, and was thus restored to quite a fair state of reflectivity.

*Dimensions etc. of mirror*

Diameter of figured surface = 7·05 ins.
Diameter of central hole = 1·35 ,,
Focal length = 6 ft. 3·5 ins.

*Results of Foucault test*

Tested on 1924, May 13, from 23.30 to 23.45 G.M.T.
Temperature at 23.30 = 53°·25 F.
,, 23.45 = 53°·5 F.

*General figure of mirror*

Very even from edge to centre, except for a fairly narrow and shallow zone of short focus just outside the central hole.

*Zonal test*

Measured $\triangle 2 - 4 = 0{\cdot}227$ inch. Theoretical $\triangle 2 - 4 = 0{\cdot}047$ inch.

The mirror is therefore considerably over-corrected, as tested under a slightly rising temperature. A falling temperature would probably increase the over-correction still further.

(C)

A 6-inch Gregorian mirror of speculum metal, lying loosely in a brass box with close-fitting brass cover. It was cleaned with ether and lemon juice and thus brought to quite a fair condition of polish.

*Dimensions etc. of mirror*

Diameter of figured surface = 5·9 ins.
Diameter of central hole = 1·2 ,,
Focal length = 2 ft. 9 ins.

*Results of Foucault test*

Tested on 1924, May 13, from 2.20 to 2.30 G.M.T.
Temperature at 2.20 = 52°·25 F.
,, 2.30 = 52°·75 F.

*General figure of mirror*

Very slightly uneven, with a broadish shallow zone of long focus just outside the central hole. These defects, however, are slight, and the out-of-focus discs, as examined with an eyepiece, are evenly bright with the pin-hole used.

*Zonal test*

Measured $\triangle 1 - 3 = 0{\cdot}282$ inch. Theoretical $\triangle 1 - 3 = 0{\cdot}068$ inch.

The mirror is thus considerably over-corrected, as tested under slightly rising temperature.

(D)

A 6½-inch glass mirror in its original brass cell, with close fitting tin cap. It is quite transparent, and appears to rest on a backing of velvet. It was cleaned with ether and has a good polish. It was doubtless used by Sir William Herschel for solar observations (see *C.S.P.* I, lvi and II, 238). It was not removed from its cell when cleaned and examined.

*Dimensions, etc., of mirror*

Total diameter = 6·7 ins.
Clear aperture in cell = 6·5 ,,
Focal length = 7 ft. 1·75 ins.

*Results of Foucault test*

Tested on 1924, May 13, 8 to 8.30 G.M.T. Temperature not noted but probably very slowly rising or nearly constant.

*General figure of mirror*

Roughly spherical. There is a small spot of long focus at the centre, and a broad shallow zone of long focus half-way from centre to edge. Otherwise the figure is even.

No zonal test was carried out, the figure being so closely spherical.

(E)

An 8½-inch glass mirror, in its original iron cell with narrow brass retaining rim and close-fitting tin cover. Like (D) it is transparent and is mounted on ? velvet. It was not removed from its cell. It was cleaned with ether and has a good polish.

*Dimensions, etc., of mirror*

Total diameter of figured surface = 8·8 ins.
Clear aperture in cell = 8·6 „
Focal length = 10 ft. 3 ins.

*Results of Foucault test*

Tested on 1924, May 13, 8.30 to 9.0 G.M.T. Temperature not noted (see under (D)).

*General figure of mirror*

Very even, except for a small central spot of long focus, surrounded by a narrow zone of short focus of radius 1 inch and a narrow zone of short focus about 1 inch from outer edge. The figure appeared so nearly spherical that a zonal test was not attempted.

(F)

A 6½-inch mirror of white glass, or "Tassi's compound" (see *C.S.P.* 1, lvi*). It was found wrapped loosely in brown paper, but is now covered with a piece of wash-leather and placed in a round padded box of pasteboard, with a well-fitting lid. It was cleaned with ether, and the polish found to be very good.

*Dimensions, etc., of mirror*

Diameter of figured surface = 6·48 ins.
Thickness = about ⅛ inch
Focal length = 7 ft. 3·25 ins.

*Results of Foucault test*

Tested on 1924, May 12, 22.30 to 23.0 G.M.T.
Temperature at 22.30 = 51°·75 F.
„ „ 23.00 = 52°·5 F.

*General figure of mirror*

Very even, except for two narrow and sharply defined zones of short focus, one at radius ·6 ± inch and the other at 2·2 ± inch.

*Zonal test*

Measured $\Delta\ 2 - 4 = 0{\cdot}406$ in. Theoretical $\Delta\ 2 - 4 = 0{\cdot}040$ inch. The mirror is thus considerably over-corrected.

* In *C.S.P.* this is misspelt "Tussi." The spelling "Tassi" is that given in Herschel's own MS. notes. The correct spelling is really "Tassie."

(G)

A 5-inch mirror of speculum metal, very thick for its diameter, especially in an annulus about the centre of the back. It is badly chipped at the edge, but the chip is mostly at the back and encroaches but little on the front surface. Half of it was cleaned and brought to quite a good polish with ether and lemon juice. The other half was left in its original condition, to show the contrast.

An attempt was made to test it by Foucault's method on 1924, June 17, but the focal length (1 ft. 6 ± ins.) proved inconveniently short for the apparatus and no zonal test was carried out. The figure appeared even, without zones, and the characteristic "parabolic" shadows were very prominent. It is probably a very good mirror.

It lies loosely in a somewhat rusted tin case with hinged lid.

(H)

A 3-inch Gregorian mirror of speculum metal. It was found in a tin case, along with (L), in a partitioned wooden box in the loft with the 20-foot telescope. It was cleaned with ether and lemon juice. Its very short focus (? 6 ± inches) made a Foucault test quite impossible with the apparatus available. The polish is in fair condition, but some of the tarnish is too deep to be removed.

(J)

This is one of three 9-inch mirrors, (J), (K), and (N), of speculum metal, all of about 10 ft. focal length, which were found, each soldered in a tin case, in a partitioned box in the loft with the 20-foot telescope. They had evidently been soldered down by Sir William Herschel, and probably formed part of his stock still unsold at the time of his death in 1822*. They were all unsoldered for the first time on 1924, May 13.

(K) and (N) were each provided with an inner cover of beaten tin, concave side to mirror, on which it lay loosely to prevent contact with the outer lid. (J) had no inner cover. Beyond this there was no sort of packing or padding in the tin cases, and the mirrors were free to shift from side to side for a total distance of about $\frac{1}{8}$ inch. When opened, their polish was found to be in almost perfect condition, though the one with no inner cover was perhaps a little less perfect than the other two. There were one or two minute circular spots on the surface of each, but no tarnish at all and only a very few specks of dust, which were easily wiped away with cotton-wool. Otherwise no attempt was made to clean or polish the surfaces in any way.

*Dimensions, etc. of mirror*

Diameter of figured surface = 8·8 ins.
Focal length = 10 ft. 1 in.

* They were probably intended for use with an unfinished 10-foot telescope. (See *C.S.P.* 1, lv and lvi.)

*Results of Foucault test*

Tested on 1924, May 13, 9 to 9.30 G.M.T.
Temperature not noted. (See under (D).)

*General figure of mirror*

Very even and regular except for a small central spot of long focus and a very faint shallow zone of short focus about $\frac{3}{8}$ from centre to edge. As regards *evenness* of figure it is the best of the three mirrors (J), (K), and (N).

The figure was so nearly spherical that no zonal test was attempted.

After being tested, the mirror, duly marked, was deposited in its case (also marked) in the cottage with the other mirrors.

(K)

Opened up on 1924, May 13. (See under (J).)

*Dimensions, etc., of mirror*

Diameter of figured surface = 8·85 ins.
Focal length = 10 ft. 3·25 ins.

*Results of Foucault test*

Tested on 1924, May 13, 9.30 to 10.0 G.M.T.
Temperature not taken. (See under (D).)

*General figure of mirror*

Very smooth and regular but for a prominent zone of short focus whose radius was about $\frac{3}{5}$ that of the whole mirror. There was also a small spot of short focus at the centre. The whole mirror appeared under the knife-edge to be of nearly spherical figure, or perhaps very slightly parabolic. The correction is probably pretty exact, but no zonal test was attempted under such difficult conditions, the theoretical aberrations being so slight with such a large focal ratio.

The mirror was, after testing, marked and deposited in the cottage. The case was also marked.

(L)

An unfinished glass mirror, about 9 inches in diameter and $\frac{1}{8}$ inch thick. It is plane and rough-ground on the back, which is, with the edge, stained with rouge. The surface is partly polished, the edges being least finished. On attempting to submit it to the Foucault test, it was found quite impossible to obtain any useful result owing to the violent flexure produced when it stood upon its edge on the testing board. Its focal length is of the order of 10 feet.

(M)

This is the mirror belonging to the 7-foot telescope that stands in the hall. It was found in the telescope and replaced in it after examination and testing. The mirror, which is of speculum metal, is mounted in a brass cell with the usual narrow retaining rim at the front. The cell is covered by a close-fitting black japanned tin lid with handle. To the back of the cell is attached a horizontal bar of iron into which two adjusting screws, worked from the bottom of the telescope outside, are threaded. The cell and mirror were detached from the tube for examination. The mirror was found to be very dusty and considerably tarnished. It was cleaned with ether and treated with lemon juice. As a result, a very fair white polish was restored, leaving comparatively little tarnish considering the long time that has elapsed since it was figured (at *least* 102 years). It was not removed from its cell for cleaning and testing.

*Dimensions, etc., of mirror*

Total diameter = 6·4 ins.
Clear aperture in cell = 6·2 ,,
Focal length = 7 ft. 2·75 ins.

*Results of Foucault test*

Tested on 1924, May 12, 7.30 to 8.0 G.M.T.
Temperature at 7.30 = 51°·75 F.
,, 8.0 = 52°·25 F.

*General figure of mirror*

A beautifully smooth curve from centre to edge, without sign of zones or other irregularities.

*Zonal test*

Measured $\Delta$ 1 − 3 = 0·162 inch. Theoretical $\Delta$ 1 − 3 = 0·260 inch. Thus it appeared somewhat *under*-corrected under a slightly rising temperature.

*Star test*

The next day the mirror was replaced in the tube of the telescope and adjusted. The flat, which had been removed and cleaned, was also adjusted, and the slider was fitted with an eyepiece of focal length 0·240 inch ($C_{12}$). This gave a power of 361, or nearly 60 to the inch. The telescope was taken out on to the lawn and tested on Arcturus and the Moon in the evening. The seeing was good but there was some disturbance of the image due to currents in the tube, which is really too narrow for the size of the mirror.

The definition given by the mirror was *excellent*.

Arcturus showed a sharply-defined round disc, with diffraction rings. The extra-focal images showed now, under a falling temperature, a *very slight over*-correction, but this had no appreciable effect on the focussed image.

The Moon was very well shown, there being just enough light for comfortable

use of this power in spite of the tarnishing of the mirrors. The shape of the second peak in Tycho was well made out and the third peak, to the west of it, could just be seen. The central craterlet in Plato was clearly seen as such, and one or two of the minute craterlets on the west half of the floor of Clavius were definitely visible. This is about as much, as regards detail, as a modern 6-inch refractor will do. The terminator was through Gassendi.

The mirror is clearly a fine piece of work.

It still remains in the telescope with the flat.

(N)

This is one of the three 9-inch mirrors of speculum metal unsoldered on 1924, May 13 (see also under (J) and (K)). As regards the condition of its polish it is the finest of the three. It was provided with an inner cover, as mentioned earlier. There was no time to test it at Slough, but it was taken to West Norwood and tested there, being afterwards exhibited at the meeting of the Royal Astronomical Society on 1924, June 13. After the meeting it was presented to W. H. Steavenson by the Rev. Sir J. C. W. Herschel.

*Dimensions, etc., of mirror*

Diameter of figured surface = 8·8 ins.
Focal length = 10 ft. 0 in.

*Results of Foucault test*

Tested at West Norwood, under constant temperature, on 1924, May 18 and June 7.

*General figure of mirror*

Sensibly spherical and very even, except for three zones of short focus: (1) of radius 1 ± inch and about $\frac{3}{4}$ inch wide, (2) about $\frac{7}{8}$ to $\frac{1}{2}$ from centre to edge and about $\frac{1}{2}$ inch wide, not at all deep, and (3) about $\frac{5}{8}$ from centre to edge and about $\frac{1}{2}$ inch wide, of moderate depth. No zonal test was attempted owing to close sphericity of mirror.

SECTION A

*Elliptical Plane Mirrors*

These range in size (minor axis) from 0·55 to 3·08 ins., all being of speculum metal. Some are provided with close-fitting covers, and these were found nearly all in excellent condition as regards their polish. A gentle rub with a clean leather, after removal of any dust, was all that was required in the way of cleaning for most of these covered mirrors. Those without covers, or with loose fitting covers, were more or less tarnished, but were brought into fair or even good condition by treatment with lemon juice. In the following list, all the mirrors from ($A_3$) to ($A_{22}$) inclusive are fitted with brass mounts and close-fitting brass covers (except ($A_8$)). Those from ($A_{23}$) to ($A_{29}$) inclusive have brass mounts, unless otherwise stated, but no covers. All were examined and, where necessary, cleaned on 1924, May 14, being measured and engraved (on cover and/or mount) on 1924, June 1.

*List of Plane Mirrors*

| As now marked | Diameter of minor axis ins. | Remarks |
|---|---|---|
| ($A_1$) | 3·08 | Brass mount, with iron cover not fitting very closely. Much tarnished when found, but brought to a pretty good polish with lemon juice. This flat was probably used with the 20-foot telescope before the latter was converted to the front view form. |
| ($A_2$) | 1·97 | Mounted on wooden block. Mirror cut at right angles to its surface. No cover; somewhat tarnished, but considerably improved with lemon juice. |
| ($A_3$) | 1·46 | Split diagonally across; good polish, but some scratches. |
| ($A_4$) | 1·48 | Many fine scratches, but polish otherwise pretty good. |
| ($A_5$) | 1·46 | Polish good, but for one patch of tarnish at the edge. A few scratches. Presented to W. H. S. on 1924, July 12. Removed Oct. 28. |
| ($A_6$) | 1·46 | Much scratched; otherwise a pretty good polish. |
| ($A_7$) | 1·49 | Pretty good polish. Detached from its mount, but the latter not missing. |
| ($A_8$) | 1·30 | No mount. Brass backing with three screw holes. Good polish, but many fine scratches. Marked "No. 1." No cover. |
| ($A_9$) | 1·16 | Polish good. Some bad scratches. |
| ($A_{10}$) | 1·12 | Polish very good. |
| ($A_{11}$) | 1·13 | Polish very good. |
| ($A_{12}$) | 1·15 | Polish very good. |
| ($A_{13}$) | 1·15 | Polish very good. |
| ($A_{14}$) | 1·10 | Polish very good. |
| ($A_{15}$) | 1·13 | Polish good. Detached from mount. |
| ($A_{16}$) | 1·10 | Polish good. |
| ($A_{17}$) | 1·12 | Polish very good. |
| ($A_{18}$) | 1·14 | Polish good; some bad scratches. |
| ($A_{19}$) | 1·13 | Polish very good, but for one small spot of tarnish. |
| ($A_{20}$) | 1·17 | Found in the 7-foot telescope (q.v.) without cover for at least 50 years. Very tarnished when found, but now, after treatment with lemon juice, the polish is poor to fair. A spare cover of brass was found for it, and it has been replaced, after engraving, in the telescope. |
| ($A_{21}$) | 1·03 | Polish fair. |
| ($A_{22}$) | 1·15 | Ground, but not polished. |
| ($A_{23}$) | 1·12 | Fair polish. |
| ($A_{24}$) | 1·16 | Ground, but not polished. |
| ($A_{25}$) | ·97 | Polish poor. |
| ($A_{26}$) | ·97 | Polish fair, some scratches. |
| ($A_{27}$) | 1·0 | Polish poor. |
| ($A_{28}$) | ·75 | Polish poor. |
| ($A_{29}$) | ·55 | Polish poor. |
| ($A_{30}$) | 1·34 | Polish pretty good. Many fine scratches. Found in ($F_{14}$) very dusty and tarnished. Cleaned and replaced on 1924, May 13. |

## Section B

*Secondary Mirrors for Gregorians*

These range in size from 0·53 to 1·4 ins. A few are provided with covers of brass, and all have brass mounts. Those without covers were found in poor condition, but considerably improved with lemon juice. The covered ones required and received no cleaning. They were all examined and, where necessary, cleaned on 1924, May 14, and measured and engraved on mount and cover on 1924, June 17. All are of speculum metal.

*List of Secondary Mirrors*

| As now marked | Diameter of minor axis ins. | Remarks |
|---|---|---|
| ($B_1$) | 1·4 | Polish moderate. No cover. |
| ($B_2$) | 1·3 | Polish good, but scratched at edge. Brass cover. |
| ($B_3$) | 1·3 | Polish good. Slightly scratched. No cover. |
| ($B_4$) | 1·2 | Polish good, except at edge. No cover. |
| ($B_5$) | 1·05 | Polish fair. No cover. |
| ($B_6$) | 1·05 | Polish good. Brass cover. |
| ($B_7$) | 1·0 | Polish fair. No cover. |
| ($B_8$) | ·75 | Polish poor, with spots. No cover. |
| ($B_9$) | ·53 | Polish very poor. No cover. |

*Note.* The remarks made as to polish in Sections A and B refer to the final condition of the mirror, *after* cleaning, where this was done.

## Sections C, D, and E

### *Eyepieces and Micrometers*

These are all of simple, and roughly similar construction. Each eyepiece is more or less cylindrical in form, being divided into two portions, which, screwing into one another, hold a single lens between them. With one exception, no eyepiece has been found to contain more than one lens. In the great majority of cases this latter is of the equi-convex form. Each mount is provided with a thread conforming, in general, to one of three standard sizes, which may be described as "large," "medium," and "small." Brass and wooden adapters have been found which would enable any of the eyepieces to be used in one and the same telescope. Two of the small eyepieces (brass-mounted) have no threads at all, and it is not quite clear how they were used.

Every lens was dismounted separately and cleaned with ether or alcohol, either on 1924, May 14 and 15, or on June 16 and 17. On the same days, after being remounted, each lens was examined with a microscope and its focal length determined with a focometer. The lenses were, in nearly every case, found to be undamaged and in excellent condition, and most of them gave admirable definition. In the case of those whose focal length was 0·75 inch or greater, this quantity was determined roughly by projection, using a wooden ruler. The results are probably correct to within about 0·1 inch. In every other case the focal length of each lens was measured carefully with a micro-focometer. The order of accuracy attained by this method varies from about 5 per cent. of the whole for those of shortest focus to less than ½ per cent. for those above 0·1 inch.

On 1924, June 17 and 18, all eyepieces and micrometers, both of wood and brass, were engraved on their mounts with the letters and numbers appropriate to them, as shown in the following lists. Some of the eyepieces were found wrapped in pieces of paper, on which were written particulars of their focal lengths in handwriting recognized by his three daughters to be that of Sir J. F. W. Herschel. These papers have been replaced round their respective eyepieces.

## Section C

### *List of Eyepieces with Brass Mounts*

| As now marked | Old marks | Focal length ins. | Focal length (J.F.W.H.) in. | Thread | Remarks |
|---|---|---|---|---|---|
| ($C_1$) | — | 2·0 ± 2·1 ± | — | Large | The only two-lens eyepiece found; two bi-convex lenses set close together. Screws for wires, but none fitted |
| ($C_2$) | — | 1·5 ± | — | None | Probably eyepiece for finder. Fitted with cross-wires |
| ($C_3$) | "320" | ·825 | — | Medium | Plain cylinder |
| ($C_4$) | "480" | ·655 | "·631" | Medium | Plain cylinder |
| ($C_5$) | — | ·534 | — | Medium | Plain cylinder |
| ($C_6$) | — | ·460 | "·439" | Medium | Plain cylinder |
| ($C_7$) | — | ·415 | — | Medium | Plain cylinder |
| ($C_8$) | — | ·390 | "·379" | Medium | Plain cylinder |
| ($C_9$) | — | ·336 | — | None | Plain small cylinder |
| ($C_{10}$) | "111" | ·308 | "·292" | Medium | Plain cylinder |
| ($C_{11}$) | — | ·250 | "·240" | Small | Milled edge |
| ($C_{12}$) | — | ·240 | "·231" | Medium | Milled edge |
| ($C_{13}$) | — | ·160 | "·152" | Small | Milled edge |
| ($C_{14}$) | — | ·139 | — | None | Plain small cylinder |
| ($C_{15}$) | — | ·116 | — | Fairly large, not standard | Shallow and broad, with milled edge. Unlike all the others. Is it an eyepiece? |
| ($C_{16}$) | — | ·098 | "·0912" | Small | Milled edge |
| ($C_{17}$) | — | ·090 | — | Small | Milled edge |
| ($C_{18}$) | — | ·089 | "·0822" | Small | Milled edge |
| ($C_{19}$) | — | ·072 | — | Small | Milled edge |
| ($C_{20}$) | — | ·069 | "·0642" | Small | Milled edge |
| ($C_{21}$) | — | ·038 | "·0379" | Small | Milled edge |
| ($C_{22}$) | — | ·0270 | "·0265" | Small | Milled edge |

## Section D

### *Eyepieces with Wooden Mounts*

These are all turned out of cocus wood, including their threads. Those from ($D_1$) to ($D_{17}$) inclusive are, when assembled, of more or less smooth cylindrical outline. The remainder are of a special design, which is described and illustrated in *M.N.R.A.S.* 84 (1923–24) 607. The lenses, owing to their diminutive size, required special care in removing and cleaning, and they were taken to London for the purpose on 1924, May 15, being brought back to Slough on 1924, June 13. When cleaned with strong nitric acid, their focal length was measured in London with the instrument used for all the other eyepieces. The upper portion or rim of the eyepieces ($D_{18}$) to ($D_{26}$) projects slightly beyond the remainder of the mounting, and this, coupled with the domed brass plates holding the lenses, serves to distinguish them at a glance from the others.

Equi-convex lenses are fitted to all the eyepieces, with the exception of ($D_4$), ($D_9$), ($D_{10}$), ($D_{13}$), and ($D_{21}$), which see for particulars.

*List of Eyepieces with Wooden Mounts*

| As now marked | Old marks | | Focal length ins. | Focal length (J.F.W.H.) in. | Thread | Remarks |
|---|---|---|---|---|---|---|
| ($D_1$) | — | — | 3·6 | — | Large | Smooth cylinder. Some red wax adhering |
| ($D_2$) | — | — | 1·55 | — | Medium | Plain long cylinder |
| ($D_3$) | — | "10" | ·47₄ | — | Medium | Plain cylinder |
| *($D_4$) | — | "22" [in ink] | ·445 | — | Medium | Plain cylinder. Plano-concave lens |
| ($D_5$) | — | "11" | ·40 | — | Medium | Plain cylinder |
| ($D_6$) | — | "14" | ·34 | — | Medium | Plain cylinder |
| ($D_7$) | — | "16" | ·336 | — | Medium | Plain cylinder |
| ($D_8$) | — | "15" | ·33 | — | Medium | Plain cylinder |
| *($D_9$) | "4" | "790" | ·282 | — | Medium | Plain cylinder. Bi-concave lens |
| *($D_{10}$) | — | "3" | ·270 | — | Medium | Plain cylinder. Bi-concave lens |
| ($D_{11}$) | "27 ab$^t$" in pencil | "17" | ·22 | — | Medium | Plain cylinder |
| ($D_{12}$) | — | "18" [in ink] | ·22 | — | Medium | Plain cylinder |
| *($D_{13}$) | — | "5" | ·190 | — | Medium | Plain cylinder. Bi-concave lens |
| ($D_{14}$) | "20" | "657" | ·150 | "·1453" | Small | Shallow cylinder |
| ($D_{15}$) | "21" | "722" | ·140 | "·1295" | Small | Shallow cylinder |
| ($D_{16}$) | "22" | "775" | ·130 | "·1239" | Small | Shallow cylinder |
| ($D_{17}$) | "23" | "981" | ·105 | "·1002" | Small | Shallow cylinder |
| A ($D_{18}$) | "25" | "1504" | ·064 | — | Medium | Projecting rim. Lens rubbed on the outside |
| B ($D_{19}$) | "26" | "2100" | ·046 | — | Medium | Projecting rim. Under-surface of lens chipped |
| C ($D_{20}$) | "29" | "2589" | ·038 | — | Medium | Projecting rim. Good lens |
| D ($D_{21}$) | "32" | "4140" "Dr Fal" | ·024 | — | Medium | Projecting rim. Lens a good simple sphere |
| E ($D_{22}$) | — | — | ·023 | — | Medium | Projecting rim. Good lens, some scratches and devitrification |
| F ($D_{23}$) | — | "4294" | ·0225 | — | Medium | Projecting rim. Good lens, slightly devitrified |
| G ($D_{24}$) | "33" | "4823" | ·019 | — | Medium | Projecting rim. Good lens, nearly perfect |
| H ($D_{25}$) | "35" | "5489" | ·0175 | — | Medium | Projecting rim. Good lens, slightly devitrified |
| J ($D_{26}$) | — | — | ·0111 | — | Medium | Projecting rim. Somewhat astigmatic and slightly devitrified |

*Note I.* For references to high powers, see *C.S.P.* I, 97.

*Note II.* The lens of ($D_{26}$) was found to be missing on 1924, July 12. It was last known to be in position on 1924, May 17, but was not afterwards examined until July 12, when the loss was discovered.

A, B, C, etc. are the temporary designations used in *M.N.R.A.S.* 84 (1923–24) 607.

## Section E

### *Eyepiece Micrometers*

The working parts of these are all of brass, except the screws of the distance micrometers, which are of steel. The motions of most of the micrometers had become stiff through dirt and the drying up of their original lubricant. After

* See *C.S.P.* II, 544.

treatment with a few drops of paraffin, nearly all were brought into a fair workable condition, though most of them have lost their wires.

All, except ($E_8$), are mounted in brass or wooden mounts, the latter being provided with a large thread for attachment to the telescope; ($E_1$), however, is attached to a plain draw-tube without thread. Three of the mounts have no eyepiece in place, but each is provided with a threaded aperture of standard size for fitting the same.

All reading circles are divided on their faces.

*List of Eyepiece Micrometers*

| As now marked | Nature of micrometer | Focal length of eyepiece and nature of thread ins. | | Remarks |
|---|---|---|---|---|
| ($E_1$) | Position | 1·9 | Sliding | Entirely of brass. Direct reading on divided circle by index attached to eyepiece. Thin metal wires fixed. One thick wire revolves with eyepiece and pointer. Wires in good condition. The eyepiece and thick wire mounted on a sliding plate of brass |
| ($E_2$) | Distance (Parallel wire) | 1·65 | Large | In large wooden mount. Small brass frames and brass circle |
| ($E_3$) | Spare eyepiece for ($E_2$) | 1·50 | Large | Similar to one in micrometer |
| ($E_4$) | Distance (Parallel wire) | 1·1 | Large | In large wooden mount with large brass circle and one broken wire, apparently of hair |
| ($E_5$) | Distance (Parallel wire) | ·75 | Large | In large wooden mount with large brass silvered circle. No wire |
| ($E_6$) | Distance | ·333 | Small | In small wooden mount with small brass frames and circle. Two distance webs (of silk?) intact, though dirty |
| ($E_7$) | Position | | None | In damaged brass mount, with eyepiece plate missing. No wire. Reads on small brass circle, half exposed, which gears into outer edge of large rotating plate which is marked for fitting of silk threads. Motion works well |
| ($E_8$) | Position | | None | Like ($E_7$) but smaller, and set in wooden mount of moderate size. Latter with threaded aperture for small size eyepiece. This is evidently the micrometer described and figured in *C.S.P.* I, 37. The circle is loose on its spindle and the rotating plate stiff in places. Otherwise in order |
| ($E_9$) | Distance (Parallel wire) | | None | Brass frames only, with screw scale for counting revolutions, and small brass circle |
| ($E_{10}$) | Position | | None | Entirely of brass. Similar to ($E_7$) but complete with eyepiece plate. Latter has threaded aperture for medium size eyepieces and in this is screwed a ring adapter for small eyepieces. It has two silkworm threads, intact but dirty. It is in working order |

## Section F

### *Miscellaneous Apparatus*

This section includes various objects which cannot be classified under previous sections of this Catalogue. All were marked (with red oil paint) by Miss Eileen Herschel on 1924, July 1. Unless otherwise stated, they were found and left in the "Cottage."

($F_1$) Disc of speculum metal, 6½ inches in diameter and ¾ inch thick. One surface has been roughly smoothed, preparatory to grinding. Probably intended for a 7-foot mirror. It was originally found (in a tin case) along with (H), (J), (K), (L), (N), and (F) in a wooden box with partitions. Now in the "Cottage."

($F_2$) Finder in plain brass tube. Diameter of object-glass 1⅝ inches, of which 1·25 inches are polished and figured. Focal length of O.G. = 12·55 inches. Eyepiece fitted with metal cross-wires, which are in good condition. Lens (single bi-convex) is of focal length 1·5 inches.

($F_3$) One of six discs of metal, each 10 inches in diameter and ⅛ inch thick. This one is of zinc. All were found marked with their respective compositions in black paint.

($F_4$) A similar disc of tin.

($F_5$) " " copper.

($F_6$) " " bismuth.

($F_7$) " " antimony.

($F_8$) " " lead.

($F_9$) A quadrant by Bird, of 13 inches radius. Mounted on a mahogany board, complete with telescope and level, and in very good condition except that the micrometer motion for setting was missing. This latter was found later in a box of oddments, and the instrument is now complete but for a small brass fitting for attaching the slow motion to the arm carrying the telescope. (See *C.S.P.* I, 57, 459 note, 507.)

($F_{10}$) A 9-inch burning lens by Dollond. In wooden and brass mount on wooden pedestal. In entrance hall, close to 40-foot mirror. (See *C.S.P.* II, 87–89, III, illustration.)

($F_{11}$) Secondary mirror (convex) for a large Cassegrain reflector, 3 inches in diameter. Polish poor, with some large corroded patches. Of speculum metal in brass mount.

($F_{12}$) Sliding brass mount for eyepiece, with rackwork and pinion, 12 by 4 inches.

($F_{13}$) Sliding brass mount for eyepiece, with rackwork and pinion, 8 by 2½ inches.

($F_{14}$) "Diagonal" attachment, with 10-inch and 5-inch brass tubes welded at right angles, containing, at the junction, a plane elliptical mirror, ($A_{20}$) q.v. The whole mounted on wooden base, levelling by four iron screws on to iron plate, with brass clamping bolt through both. The smaller tube is fitted with a thread for medium sized eyepieces, and an adapter (unthreaded) of smaller size.

($F_{15}$) A refractor by Dollond, in mahogany tube. Clear aperture of O.G. = 2·7 inches. Focal length = 3 ft. 10·5 inches. Sliding eyepiece tube, fitted with Browning Huygenian eyepiece of 1 ±inch focus. (See *C.S.P.* I, xxxviii and 151, ? 459 note.)

($F_{16}$) Caroline Herschel's "Monkey Clock or Jack," used by her for counting seconds. In plain wooden case, painted black. Brass face, pendulum missing. 3 ft. 10·5 inches high.

($F_{17}$) The Regulator Clock by Shelton, presented to Sir William Herschel by Mr Aubert. Now in hall of Observatory House; in working order but quality of its present performance has not been ascertained. It has been going continuously, except during removals, etc., since it was first given to Sir William Herschel. (See *C.S.P.* I, 459 note, and 515.)

($F_{18}$) The "Zone Clock" used in conjunction with the 40-foot telescope. One of the bells (the one on the left, viewed from the front) is missing. (See *C.S.P.* I, 520 illustration.)

($F_{19}$) A signal bell with two clappers. Formerly attached to the mechanism which actuated the observing gallery of the 40-foot telescope. (See *C.S.P.* I, 523 illustration.)

($F_{20}$) Two gongs of different pitch, mounted on one stem, each with a clapper actuated by rotating iron drum, after the manner of the "Zone clock" ($F_{18}$), q.v. The whole mounted on a wooden stand, painted green. Possibly this is an earlier form of zone clock, and may be the one used with the 20-foot telescope before the larger model ($F_{18}$) was constructed.

($F_{21}$) Circular lead polisher, with pitch adhering to it. 8 inches in diameter, 1·4 inches thick.

($F_{23}$) Iron ratcheted polishing frame for mirrors up to 7 inches diameter.

($F_{23}$) Iron polishing frame for mirrors up to 4·5 inches diameter.

($F_{24}$) Iron ring holder for polisher, with iron fork handle, fitted with springs for engagement with rachet.

($F_{25}$) Sir William's lathe with sundry tools. In good order.

($F_{26}$), ($F_{27}$) Pair of octagonal wooden blocks, 7½ inches each in diameter. Probably used as formers for 7-foot tubes.

($F_{28}$) A 7-inch circular block of wood, with small anvil attached.

($F_{29}$) A circular wooden polisher, of mahogany, 8·9 inches in diameter at back, ·8 inch thick. The face smooth and slightly convex with a few particles of pitch adhering thereto.

($F_{30}$) An old brass orrery, 12 inches in diameter, mounted on dodecagonal wood base. The whole considerably out of order.

($F_{31}$) A set of brass mounts for eyepieces, without lenses; five of medium thread, three of small thread, and two of very small thread. Also three incomplete mounts (upper portions only). A chip pill-box labelled: "Apertures and carrying plates," and containing a number of small stamped plates of thin brass, similar to those used for mounting the lenses in eyepieces ($D_{18}$) to ($D_{20}$), q.v. Double brass adapter (with large thread) to take eyepieces of medium and small thread. Brass screw-cap for eye-tube, with central hole for centering and adjusting mirrors. (Found among apparatus of Sir J. F. W. Herschel on 1924, Oct. 27.)

($F_{32}$) A set of wooden eyepiece mounts and adapters, some incomplete, and all without lenses; one mount of large thread, four of medium, and two of small thread; two cocus wood adapters with large thread, one of light wood of medium thread, and one threadless mount for a lens (probably not meant for an eyepiece) of light wood. Small cocus wood eyepiece mount, with internal thread and pitch adhering to it. Many dents and scratches. (Found among apparatus of Sir J. F. W. Herschel on 1924, Oct. 27.)

($F_{33}$) Tube for a 10-foot reflector. Of deal, painted light grey. For the most part in good condition, but a portion of the wood at the open end is missing and the lower end is much riddled by worm-holes for the space of about 18 inches, and the same applies to the mirror-door. Of the latter the hinges are in good order, but the hasp is nearly broken away from the rotting wood. There is the usual key-hole and two adjusting screws, one on either side of it. The metal fitting for flat and eyepiece is missing.

Length of tube = 10 ft. ⅜ in.

Internal diameter = 10 inches.